EXPERIMENTS S008 AND D013

VISUAL ACUITY AND VISIBILITY

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INTRODUCTION

Reports by Project Mercury crewmembers of sighting small objects on the ground prompted the initiation of a controlled visual-acuity experiment which was conducted on the Gemini V and VII missions. The primary objective of Experiments S008 and D013 was the measurement of the visual acuity of the crewmembers before, during, and after long-duration space flights to ascertain the effects of a long-duration spacecraft environment. The secondary objective was to test the use of basic visual-acuity data, combined with measured optical properties of ground-based objects and their natural lighting, and the optical properties of the atmosphere and the spacecraft window. Data on these topics could be used for prediction of the limiting naked-eye visual capability of the crewmen to discriminate small objects on the surface of the earth in daylight.

INFLIGHT VISION TESTS

Inflight Vision Tester

Throughout the Gemini V and VII flights, the visual performance of the crewmembers was tested one or more times each day by means of an inflight vision tester. This was a small, self-contained, binocular optical device that contained a transilluminated array of 36 high-contrast and low-contrast rectangles. Half of the rectangles were oriented vertically and half were oriented horizontally in the field of view. Rectangle size, contrast, and orientation were randomized, the presentation was sequential, and the sequences were nonrepetitive. Each rectangle was viewed singly at the center of a 30° adapting field, the apparent luminance of which was 116 foot-lamberts. Both crewmembers made forced-choice judgments on the orientation of each rectangle and indicated their responses by punching holes in a record card. Electrical power for illumination within the instrument was derived from the spacecraft.

The space between the eyes of the crewman and the sloping inner surface of the spacecraft window (8 to 9 inches) were important constraints on the size of the instrument. The superior visual performance of all crewmembers, as evidenced by clinical

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test scores, made it necessary to use great care in alinement of the instrument with the eyes of the observer, since the eyes, not the instrument, set the limit of resolution.

To achieve this, the permissible tolerance of decentering between a corneal pole and the corresponding optical axis of the eyepiece was less than 0.005 inch. This tolerance was met by use of a biteboard, equipped with a dental impression of the crewmember, to utilize the fixed geometrical relation between his upper teeth and his eyes. A photograph of the inflight vision tester is shown in figure 1.

Selection of the Test

The choice of test was made after careful study and many interacting requirements were considered. For example, if the visual capabilities of the crewmen should change during the long-duration flight, it would be of prime importance to measure the change in such a way that the inflight ability of man to recognize, classify, and identify landmarks or unknown objects on the ground or in space could be predicted. These higher order visual discriminations depend upon the quadratic content of the difference images between alternative objects, but almost all of the conventional patterns used in testing vision yield low-precision information on this important parameter. Thus, the prediction requirement eliminated the use of Snellen letters, Landolt rings, checkerboards, and all forms of detection threshold tests.

The readings must not go off the scale if visual changes should occur during flight. This requirement for a broad range of testing was not readily compatible with the desire to have fine steps within the test and yet have sufficient replication to ensure statistically significant results.

It also was desirable that the pattern chosen for the inflight vision tester be compatible with that used on the ground where search contamination of the scores must be carefully avoided; this consideration made any conventional detection-threshold test undesirable. The pattern on the ground was in sight for at least 2 minutes during all usable passes, but variations caused by atmospheric effects, geometrical foreshortening, directional reflectance characteristics, and so forth made it necessary to select a test which could be completed in a 20-second period centered about the time of closest approach.

The optimum choice of test was the orientation discrimination of a bar that was narrow enough to be unresolved in width but long enough to provide for threshold orientation discrimination. The size and apparent contrast of all the bars used in the test were sufficient to make them readily detectable, but only the larger members of the series were above the threshold of orientation discrimination. These two thresholds are more widely separated for the bar than for any other known test object. The inherent quadratic content of the difference image between orthogonal bars is of greater magnitude than the inherent quadratic content of the bar itself. Interpretation of any changes in the visual performance of the crewmembers is, therefore, more generally possible on the basis of orientation-discrimination thresholds for the bar than from any other known datum.

Rectangles in the Vision Tester

The rectangles presented for viewing within the inflight vision tester were reproduced photographically on a transparent disk. Two series of rectangles were included; the major series was set at a contrast of -1, and the minor series was set at about one-fourth of this value. The higher contrast series constituted the primary test and was chosen to simulate the expected range of apparent contrast presented by the ground panels to the eyes of the crewmen in orbit. The series consisted of six sizes of rectangles. The sizes were over a sufficient range to guard against virtually any conceivable change in the visual performance of the crewmembers during the long-duration flight. The size intervals were small enough, however, to provide a sufficiently sensitive test.

The stringent requirements imposed by conditions of space flight made it impossible to use as many replications of each rectangle as were desirable from statistical considerations. After much study, it was decided to display each of the six rectangular sizes four times. This compromise produced a sufficient statistical sample to make the sensitivity of the inflight test comparable to that ordinarily achieved with the most common type of clinical wall chart. This sensitivity corresponds roughly to the ability to separate performance at 20/15 from performance at 20/20. It was judged that this compromise between the sensitivity of test and the range of variables tested was the proper one for this investigation.

A secondary test at lower contrast was included as a safeguard against the possibility that visual performance at low contrast might change in some different way. Because only 12 rectangles were assignable within the inflight vision tester for the low-contrast array, it was decided to use only three widely different rectangle sizes, and to present each of these sizes four times.

Because of the accelerated launch schedule of the Gemini V mission, it was not possible to use the flight instrument for preflight experiments. Preflight data were, therefore, obtained with the first of the inflight vision testers (serial number 1), whereas the last instrument to be constructed (serial number 5) was put on board the spacecraft. The two instruments were optically identical except for their 12 low-contrast rectangles, capable of measurement of a contrast of -0.332 and -0.233, respectively. On the Gemini VII mission, all the reported data (preflight, inflight, and postflight) were obtained with serial number 5 tester.

Analysis of Correct Scores on the Gemini V Mission

A comparison of the correct scores made by the Gemini V crewmembers on the ground (preflight) and in flight can be used to ascertain whether their observed visual performance differed in the two environments or changed during the 7-day mission. The correct scores from the low-contrast and high-contrast series in the vision tester are shown in figure 2 for both crewmembers. The results of standard statistical tests applied to these data are shown in tables I to IV. All Student's t tests contain no significant difference in means. All Snedecor's F tests contain no significant difference in variances at the $p < 0.05$ level, with the exception of the high-contrast comparison by the command pilot which shows no significant difference at the $p < 0.01$ level. Comparisons between the inflight data collected at the beginning of the mission with that collected at the end of the mission are made in tables III and IV. All Student's t tests

and Snedecor's F tests show no significant difference at the $p \leq 0.05$ level, with the exception of the F test on the low-contrast comparison by the pilot which contains no significant contrast at the ≤ 0.01 level.

These statistical findings support the null hypothesis advanced by many scientists before the Gemini V mission. Examination of the sensitivity of the test must next be considered.

Analysis of Correct Scores on the Gemini VII Mission

A comparison of the correct scores made by the Gemini VII crewmembers on the ground (preflight) and in flight can be used to ascertain whether their observed visual performance differed in the environments or changed during the 14-day mission. The correct scores from the low-contrast and high-contrast series in the vision tester are shown for both crewmembers in figure 3. The results of standard statistical tests applied to these data are shown in tables V and VI.

Comparisons between preflight and inflight data are given in tables I and II. All Students's t tests showed no significant difference in means. All Snedecor's F test results contained no significant difference in variances at the $p \leq 0.05$ level, with the exception of the low-contrast comparison by the command pilot which contained a weakly significant difference at the $p \leq 0.01$ level.

Comparisons between the inflight data at the beginning of the mission with those at the end of the mission are made in tables VII and VIII. All Student's t tests and Snedecor's F tests showed no significant difference at the $p \leq 0.05$ level, with the exception of the F test on the low-contrast comparison by the command pilot which showed no significant contrast at the $p \leq 0.01$ level. These statistical findings also provide additional support for the null hypothesis advanced by many scientists before the Gemini missions.

Preflight Physiological Base Line

Design of the inflight vision tester and the ground-sighting experiments (to be described in another section) and the interpretation of the results from both experiments imposed the constraint that a preflight physiological base line be obtained for both crewmembers. For this purpose, a NASA van was equipped as a portable vision-research laboratory, was moved to the Manned Spacecraft Center (MSC), Houston, Texas, and was operated by Visibility Laboratory personnel. A cutaway drawing of this research van is shown in figure 4. The crewmen, seated at the left, viewed rear-screen projections from an automatic projection system located in the opposite end of the van. Each crewman participated in several sessions in the laboratory van, during which they became experienced in the psychophysical techniques of the rectangle orientation-discrimination visual task. A sufficiently large number of presentations were made to secure an adequate statistical sample. The forced-choice visual thresholds for the discrimination task of the crewmembers were measured accurately, and their response distributions were determined so the standard deviations and confidence limits of preflight visual performance could be determined.

Gemini V mission. - A logarithmic plot of the preflight visual thresholds of the pilot for the rectangle orientation-discrimination task is shown in figure 5. The solid-angular subtense of the rectangles is plotted along the horizontal axis because both the inflight vision tester and the ground-observation experiments used angular size as the independent variable. The solid line in this figure represents the forced-choice rectangle-orientation threshold of the pilot at the $p \leq 0.05$ level. The dashed curves indicate the $-\sigma$, $+\sigma$, and $+2\sigma$ levels in terms of contrast. The six circled points in the upper row indicate the angular sizes of the high-contrast ($C = -1$) rectangles presented by the inflight vision tester. The three circled points of the middle and lower rows show the angular sizes of the low-contrast rectangles used in the training unit (number 1) and the flight unit (number 5), respectively.

By the use of figure 5, the separate discriminations recorded on the record cards in the inflight vision tester can be used to determine a threshold of angular size. These thresholds are plotted for the high-contrast and low-contrast tests of the command pilot (figs. 6 and 7), and of the pilot (figs. 8 and 9). In these four figures, the horizontal solid line represents the forced-choice rectangle-orientation threshold and the horizontal broken lines represent statistical confidence limits in terms of angular size.

These four figures also support the null hypothesis, and their quantitative aspect constitutes a specification of the sensitivity of the test. Thus, as planned, changes in visual performance comparable with those on a one-line conventional clinical wall chart would have been detected. Therefore, preflight threshold data can be used to predict the limiting visual-acuity capabilities of humans during space flight, provided adequate physical information exists concerning the object, its background, its atmospheric effects, and the spacecraft window. A test of such predictions was also performed and is described in other sections of this report.

Gemini VII mission. - Thresholds and confidence limits for the vision tester data collected by the Gemini VII command pilot are shown in figures 10 and 11. Similar data collected by the Gemini VII pilot are shown in figures 12 and 13.

These eight figures also support the null hypothesis, and their quantitative aspect constitutes a specification of the sensitivity of the test. Thus, as planned, variations in visual performance comparable with a change of one line on a conventional clinical wall chart would have been detected. Preflight threshold data can, therefore, be used to predict the limiting visual-acuity capabilities of humans during space flight, if adequate physical information exists concerning the object and its background, atmospheric effects, and the spacecraft window. A test of such predictions was also performed and is described in the following section.

GROUND OBSERVATIONS

Equipment

The experimental equipment consisted of an inflight photometer (used to monitor ambient light scattered by the spacecraft window); the test patterns at two ground-based observation sites; instrumentation for atmospheric, lighting, and pattern measurements at both sites; and a laboratory facility for training the crewmembers to perform visual-acuity threshold measurements and for acquisition of a preflight

physiological base line descriptive of their visual performance and its statistical fluctuations. This equipment, except the last-mentioned item, is described as follows.

Spacecraft window photometer. - A photoelectric inflight photometer was mounted near the lower right corner of the pilot-side window of the Gemini V spacecraft (fig. 14) to measure the amount of ambient light scattered by the window into the path of sight at the moment when observations of the ground-based test patterns were made. The photometer (fig. 15) had a narrow (1.2°) circular field of view, which was directed through the pilot-side window and into the opening of a small black cavity a few inches outside the window. The photometric scale was linear and extended from approximately 60 to 3000 foot-lamberts on the Gemini V mission and from approximately 12 to 3000 foot-lamberts on the Gemini VII mission. Because the apparent luminance of the black cavity was always much less than the minimum luminance just noted for each mission, any reading of the inflight photometer was ascribable to ambient light scattered by the window. Typical data acquired during passes of the Gemini V spacecraft over the Laredo site are shown in figure 16. This information, combined with data on the beam transmittance of the window and with data on the apparent luminance of the background squares in the ground pattern array, enabled the contrast transmittance of the window at the moment of observation to be calculated. Uniformity of the window could be tested by removal of the photometer from its positioning bracket and making a hand-held scan of the window, using a black region of space in lieu of the black cavity. A direct-reading meter incorporated in the photometer enabled the command pilot to observe the photometer readings while the pilot scanned his window for uniformity. A corresponding scan of the command pilot window could be made in the same way. Photometric data were sent to the ground by real-time telemetry. Electrical power for the photometer was entirely provided by batteries within the instrument.

Ground observation sites. - Sites for observations by the Gemini V crewmembers were provided 40 miles north of Laredo, Texas (fig. 17), and 90 miles south of Carnarvon, Australia (figs. 18 and 19). At the Texas site, 12 squares of plowed, graded, and raked soil 2000 by 2000 feet were arranged in a matrix of four squares deep and three squares wide. White rectangles of Styrofoam-coated wallboard were laid out in each square. Their length decreased in a uniform logarithmic progression from 610 feet in the northwest corner (square number 1) to 152 feet in the southwest corner (square number 12) of the array. Each of the 12 rectangles was oriented in one of four positions (north-south, east-west, or diagonal), and the orientations were random within the 12-member series. Preflight knowledge of the rectangle orientations was withheld from the crewmembers, because their task was to report these orientations. Provision was made for changing the rectangle orientations between passes and for adjusting their size in accordance with anticipated slant range, solar elevation, and the visual performance of the crewmen on preceding passes. The observation site in Australia was somewhat similar to the Texas site, but details are unnecessary in this report because no observations were made.

The Australian ground-observation site was not manned during the Gemini VII mission because the afternoon time of launch precluded usable daytime overpasses there until the last day of the mission. The 82.5° launch azimuth used for the Gemini VII mission prevented the use of an otherwise highly desirable ground site in the California desert near the Mexican border. Weather statistics for December made the use of the Texas site appear dubious, but no alternative was available. The afternoon launch made midday passes over this site available on each day of the mission. Experience gained on the Gemini V mission indicated the need for a more prominent orientation marking. This was provided by placing east-to-west strips of crushed

white limestone (26 feet wide and 2000 feet long) across the center of each of the four north background squares in the array. Thus, only eight test rectangles were used in a 2 by 4 matrix on the center and south rows of background squares (fig. 20). The largest and smallest rectangles were the same size as those used on the Gemini V mission.

Instrumentation. - Instrumentation at both ground sites consisted of a single tripod-mounted, multipurpose, recording photoelectric photometer (figs. 21 and 22) capable of acquisition of all data needed to specify (at the moment of observation) the apparent contrast of the pattern as seen from the spacecraft. The apparent luminance of the background squares, needed for evaluation of the contrast loss caused by the spacecraft window, was also ascertained by use of this instrument. A 14-foot mobile tower, constructed of metal scaffolding and attached to a truck, supported the tripod-mounted photometer high enough above the ground to enable observation of the plowed surface of the background squares. This arrangement is shown in figures 23 and 24.

Observations Made on the Gemini V Mission

Observation of the Texas site was first attempted on revolution 18, but fuel-cell difficulties, which prohibited use of the platform, were apparently responsible for lack of acquisition of the site.

The second scheduled attempt to see the Laredo pattern was on revolution 33. Acquisition of the site was achieved by the command pilot but not by the pilot, and no read-out of rectangle orientation was made.

At the request of the experimenters, the third attempt to see the Laredo site, originally scheduled for revolution 45, was made on revolution 48 to secure a higher sun and a shorter slant range. Success was achieved on this pass and is described in the following section.

Unfavorable cloud conditions caused the fourth scheduled observation at the Texas site, on revolution 60, to be canceled. Thereafter, lack of thruster control made observation of the patterns impossible, although excellent weather conditions prevailed on three scheduled occasions at Laredo (revolutions 75, 92, and 107) and once at the Australian site (revolution 88). Long-range visual acquisition of the smoke markers used at both sites was reported in each instance, but the drifting spacecraft was not properly oriented near the closest approach to the pattern to enable observations to be made. A fleeting glimpse of the Laredo pattern during drifting flight on revolution 92 made it possible for the crewmen to photograph it with hand-held cameras. Another fleeting glimpse of the pattern was reported on revolution 107. On revolution 107, roll rates were neutralized by use of thrusters prior to the pass over Laredo, and although the command pilot reported a fleeting glimpse of the pattern at closest approach, the viewing time was not sufficient for him to read successfully the orientation of the rectangles.

Results of Observations Made on the Gemini V Mission

Quantitative observation of ground markings was achieved only once during the Gemini V mission. This observation was made during revolution 48 at the site near

Laredo at 18:16:14 G.m.t. on the third day of the flight. Despite acquisition of the smoke marker by the command pilot and acquisition of the target pattern itself long before the point of closest approach, the pilot could not visually acquire the markings until the spacecraft had been turned to eliminate sunlight incident upon his window. Telemetry records from the inflight photometer show that the pilot-side window produced a heavy veil of scattered light until the spacecraft was rotated. Elimination of the morning sun on the pilot-side window enabled the pilot to make visual contact with the pattern in time to make a quick observation of the orientation of some rectangles. It may be noted that, during approach, the reduction of contrast caused by light scattered by the window was more severe than was that caused by light scattered by the atmosphere.

An ambiguity exists between the transcription of the radio report made at the time of the pass and the written record in the flight log. The writing was made "blind" while the pilot was looking at the pattern; it is a diagram drawn in the manner depicted in the Gemini V flight plan, the mission operation plan, the description of experiment, and other documents. The orientation of the rectangles in the sixth and seventh squares appears to have been correctly noted. The verbal report given several seconds later correctly records the orientation of the rectangle in the sixth square, if it is assumed that the spoken words describe the appearance of the pattern as seen from a position east of the array while going away from the site.

Despite the hurried nature of the only apparently successful quantitative observation by the pilot of a ground site during the Gemini V mission, there seems to be a reasonable probability that the sighting was a valid indication of correct discrimination of the rectangles in the sixth and seventh squares. Because the pilot did not respond to squares 8 through 12, it can only be inferred that the threshold of the pilot was at square 6 or greater.

Tentative values of the apparent contrast and angular size of the sixth and seventh rectangles at the Laredo site at the time of the observation were plotted (fig. 25). The solid line represents the preflight visual performance of the pilot as measured in the vision-research van. The dashed lines represent the 1σ and 2σ limits of his visual performance. The positions of the plotted points indicate that his visual performance at the time of revolution 48 was within the statistical range of his preflight visual performance.

Observations Made on the Gemini VII Mission

Observations of the Texas site were made on revolutions 16, 17, and 31 during very favorable weather conditions. Heavy clouds blanketed the site throughout the remainder of the mission, however, and no further observations were possible. Contamination of the outer surface of the pilot-side window made observation of the pattern difficult and made the result uncertain. The contamination, observed to have occurred during launch, was mapped during revolution 19 by means of a window scan with the inflight photometer in the manner previously described. Some numerical results of this scan are given in figure 26, and figure 27 is a photograph of a shaded pencil sketch intended to portray the appearance of the window as deduced from the telemetered scan curves. Comparison of this sketch with a similar one made by the pilot during the flight revealed good correlation.

The command pilot window was not measurably contaminated on its inboard side (figs. 26 and 27). Successful observations of the pattern were made on revolutions 17 and 31 by the command pilot through the clear portion of the window. Direct sunlight was not incident upon the window during these observations.

Results of Observations Made on the Gemini VII Mission

The results of observations made by the command pilot on revolutions 17 and 31 of the Gemini VII mission are shown in figure 28. These observations occurred at 27: 04: 49 and 49: 26: 48 g. e. t. on the second and third days of the flight, respectively.

In figure 28, the circled points represent the apparent contrast and angular size of the largest rectangles in the pattern. Apparent contrast was calculated on the basis of the following.

1. Measured directional luminances of the white panels and their backgrounds of plowed soil

2. Atmospheric optical properties measured in the direction of the path of sight to the point of closest approach

3. A small allowance for contrast loss in the spacecraft window based upon window-scan data and readings of the inflight photometer at the time of the two observations

Angular sizes and apparent contrast values were both of somewhat larger magnitudes for revolution 31 than for revolution 17 because the slant range was shorter and because the spacecraft passed north of the site, thereby causing the background soil to appear darker (compare figure 20 with figure 29). The orientations of these rectangles, indicated by double circles, were reported correctly, but those represented by single circles were either reported incorrectly or were not reported at all. The positions of the data points for the Gemini VII command pilot are indicative that his visual performance was precisely in accordance with his preflight visual thresholds.

CONCLUSIONS

Both objectives of Experiments S008 and D013 were achieved successfully. Data from the inflight vision tester showed that no change was detected in the visual performance of any of the four crewmembers of the Gemini V and VII missions. Results from observations of the site near Laredo, Texas, confirmed that the visual performance of the crewmen during space flight was within the statistical range of their preflight visual performance. The results also demonstrated that visual data collected in the laboratory can be combined with environmental optical data to predict correctly the limiting visual capability of humans to discriminate small objects on the surface of the earth in daylight.

TABLE I. - VISION TESTER SCORES OF THE COMMAND PILOT (GEMINI V MISSION)

Parameter	Contrast is -1		Contrast is -0.23	
	Ground	Space	Ground	Space
Number	7	9	7	9
Mean	17.6	18.4	8.6	8.3
Standard deviation	2.3	0.96	1.3	1.4
t	0.96		0.31	
$t_{0.05}$	2.14		2.14	
F	6.12		1.02	
$F_{0.05}$	3.58		3.58	
$F_{0.01}$	6.37			

TABLE II. - VISION TESTER SCORES OF THE PILOT (GEMINI V MISSION)

Parameter	Contrast is -1		Contrast is -0.23	
	Ground	Space	Ground	Space
Number	7	9	7	9
Mean	20.7	20.7	9.7	8.6
Standard deviation	2.7	1.7	1.2	2.0
t	0		1.13	
$t_{0.05}$	2.14		2.14	
F	2.79		2.43	
$F_{0.05}$	3.69		4.82	

TABLE III. - GEMINI V MISSION VISION TESTER SCORES OF THE COMMAND PILOT (INFLIGHT TREND)

Parameter	Contrast is -1		Contrast is -0.23	
	First 4	Last 4	First 4	Last 4
Number	4	4	4	4
Mean	18.2	18.8	8.5	8.5
Standard deviation	0.83	1.1	0.87	1.8
t	0.68		0	
$t_{0.05}$	2.45		2.45	
F	1.73		4.33	
$F_{0.05}$	9.28		9.28	

TABLE IV. - GEMINI V MISSION VISION TESTER SCORES OF THE PILOT (INFLIGHT TREND)

Parameter	Contrast is -1		Contrast is -0.23	
	First 4	Last 4	First 4	Last 4
Number	4	4	4	4
Mean	21.3	19.5	8.8	8.75
Standard deviation	1.5	1.1	2.8	0.83
t	1.64		0	
$t_{0.05}$	2.45		2.45	
F	1.96		11.19	
$F_{0.05}$	9.28		9.28	
$F_{0.01}$	--		29.5	

TABLE V. - VISION TESTER DATA FOR THE COMMAND PILOT

(GEMINI VII MISSION)

Parameter	Contrast is -1		Contrast is -0.23	
	Ground	Space	Ground	Space
Number	11	14	11	14
Mean	20.0	19.9	8.45	8.4
Standard deviation	1.3	1.6	0.78	1.7
t	0.12		0.017	
$t_{0.05}$	2.07		2.07	
F	1.49		4.74	
$F_{0.05}$	2.89		2.89	
$F_{0.01}$	4.66		4.66	

TABLE VI. - VISION TESTER DATA FOR THE PILOT (GEMINI VII MISSION)

Parameter	Contrast is -1		Contrast is -0.23	
	Ground	Space	Ground	Space
Number	9	14	9	14
Mean	20.9	20.0	9.1	9.1
Standard deviation	1.4	1.6	0.74	1.4
t	1.29		0.073	
$t_{0.05}$	2.08		2.08	
F	1.17		3.64	
$F_{0.05}$	3.26		3.26	
$F_{0.01}$	5.62		5.62	

TABLE VII. - GEMINI VII MISSION VISION TESTER DATA FOR THE COMMAND PILOT (INFLIGHT TREND)

Parameter	Contrast is -1		Contrast is -0.23	
	First 5	Last 5	First 5	First 5
Number	5	5	5	5
Mean	19.0	20.0	8.0	9.0
Standard deviation	1.4	1.4	1.3	1.8
t	1.00		0.91	
$t_{0.05}$	2.31		2.31	
F	1.00		2.00	
$F_{0.05}$	6.39		6.39	

TABLE VIII. - GEMINI VII MISSION VISION TESTER DATA FOR THE PILOT (INFLIGHT TREND)

Parameter	Contrast is -1		Contrast is -0.23	
	First 5	Last 5	First 5	Last 5
Number	5	5	5	5
Mean	19.8	20.4	8.8	9.2
Standard deviation	1.3	1.5	1.2	1.6
t	0.60		0.40	
$t_{0.05}$	2.31		2.31	
F	1.27		1.88	
$F_{0.05}$	6.39		6.39	

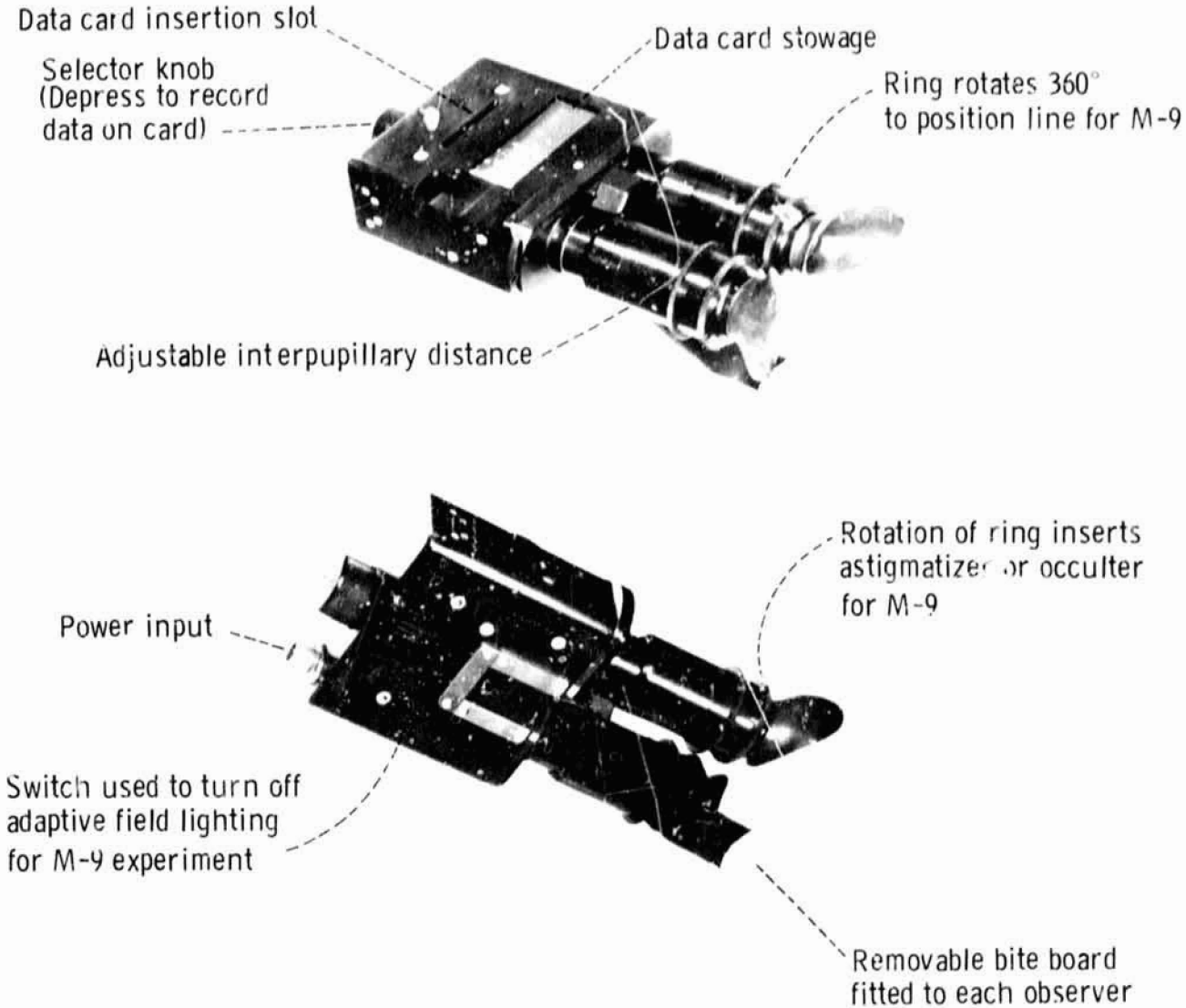

Figure 1. - Inflight vision tester.

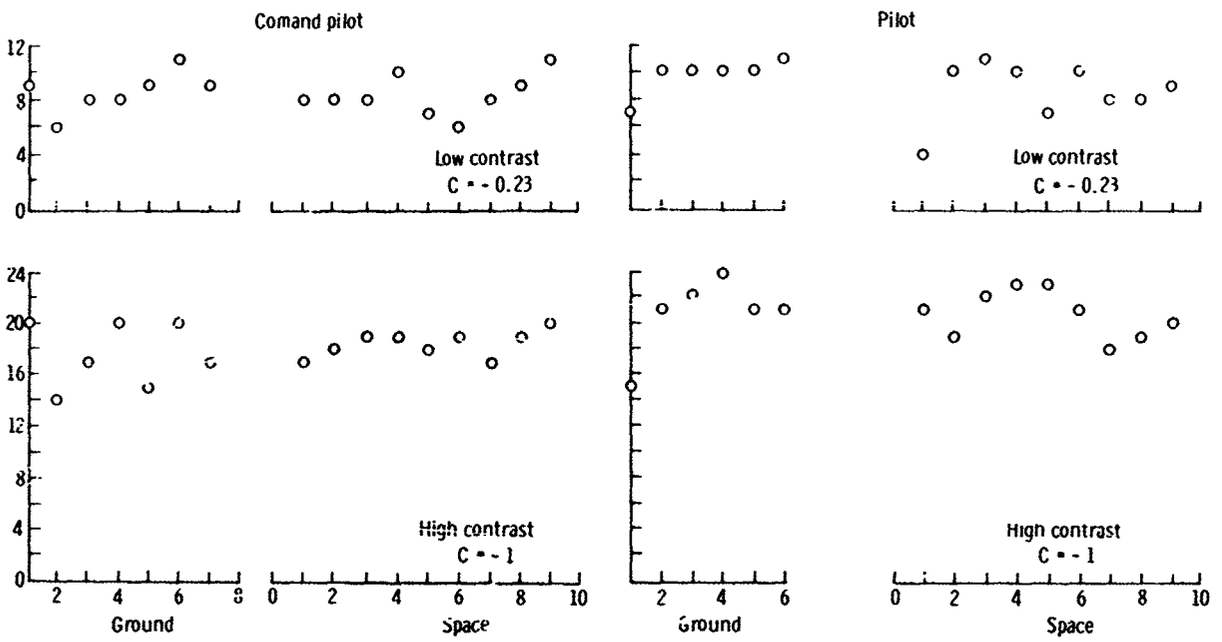

Figure 2. - Vision-tester scores for the Gemini V crewmen.

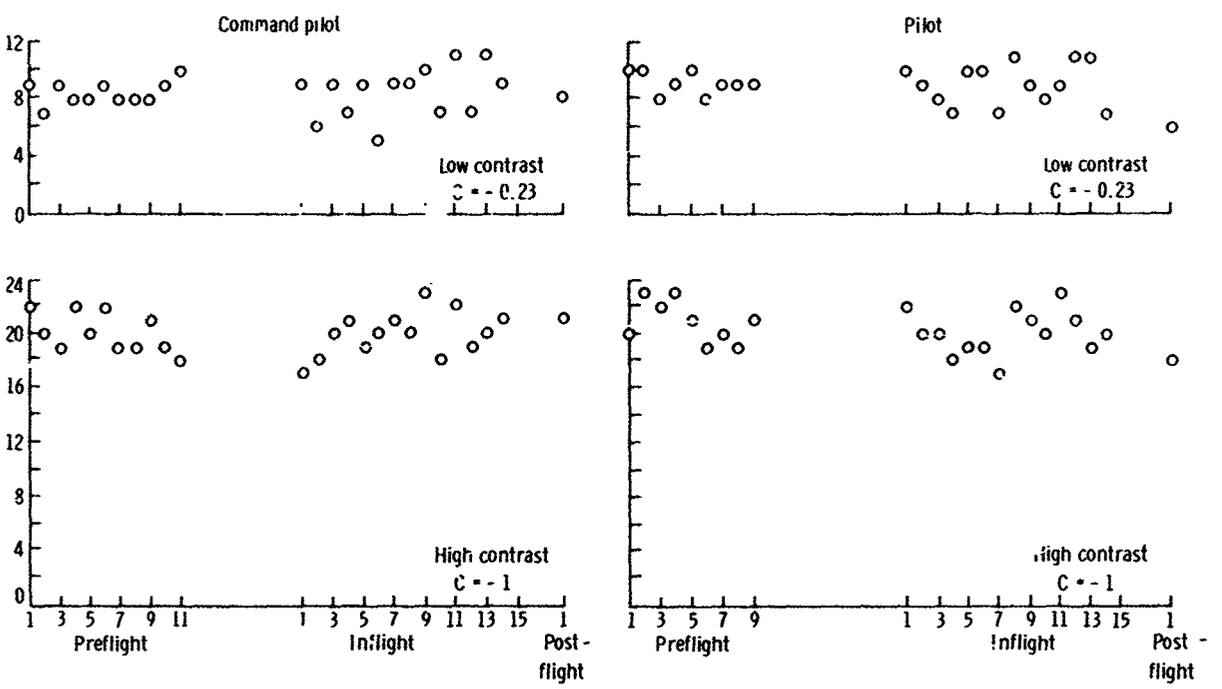

Figure 3. - Vision-tester scores for the Gemini VII crewmen.

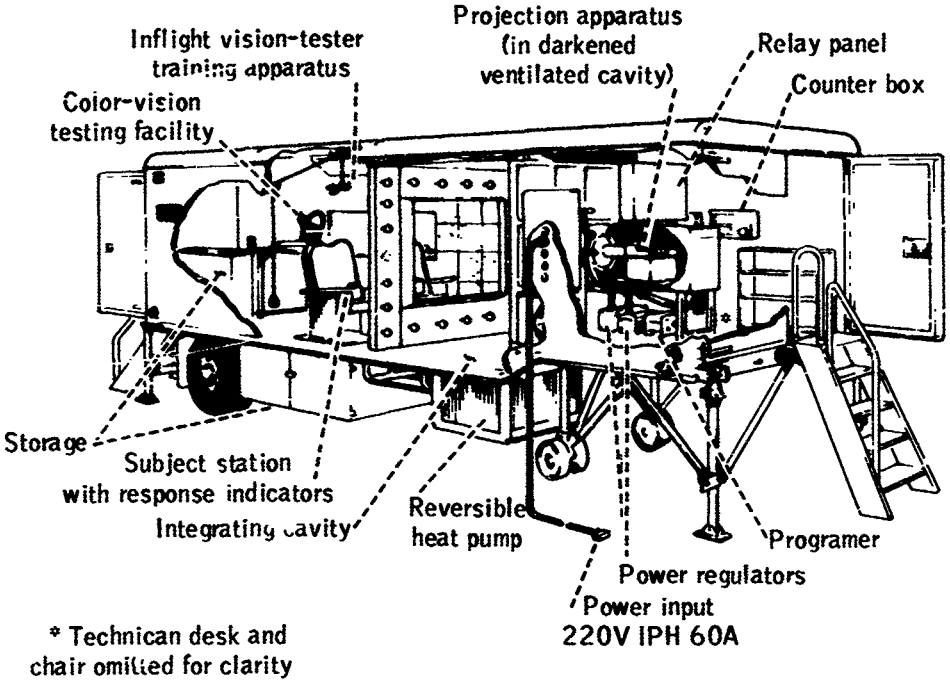

Figure 4. - Vision research and training van.

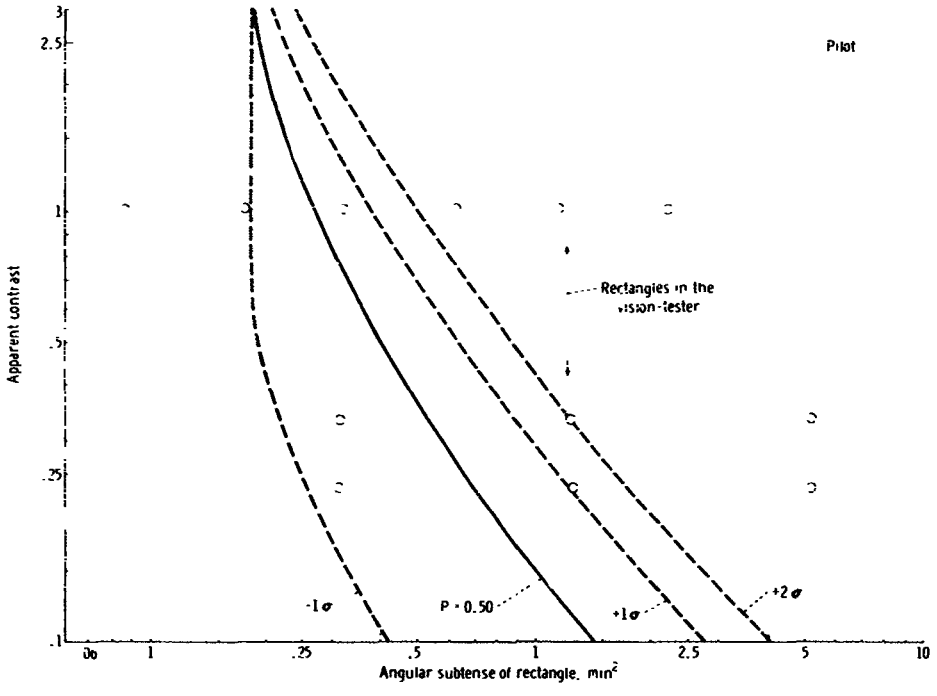

Figure 5. - Plot of preflight visual thresholds for the Gemini V pilot.

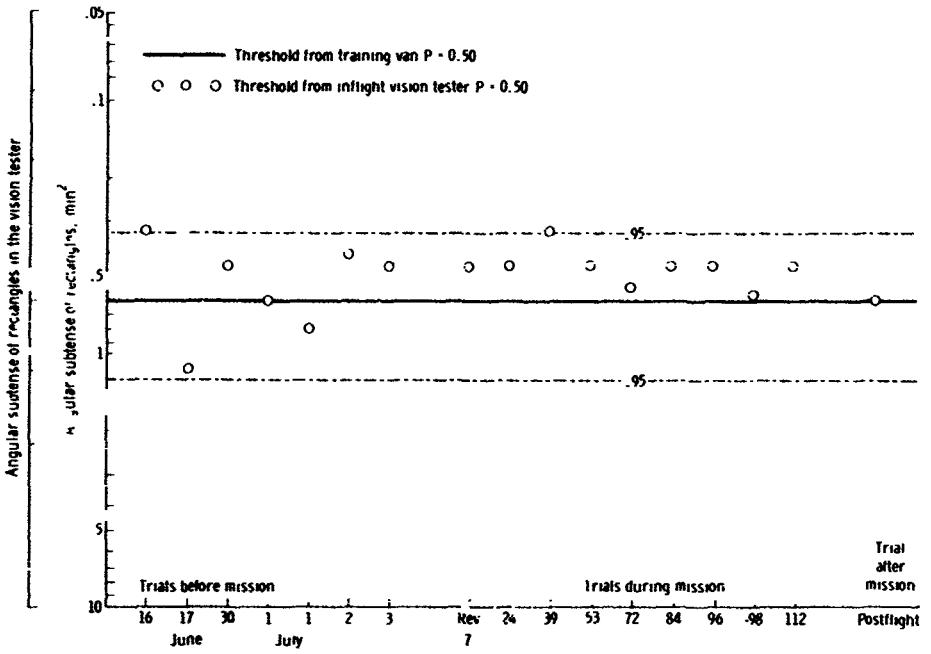

Figure 6. - Rectangle discrimination thresholds (C = -1) for the Gemini V command pilot.

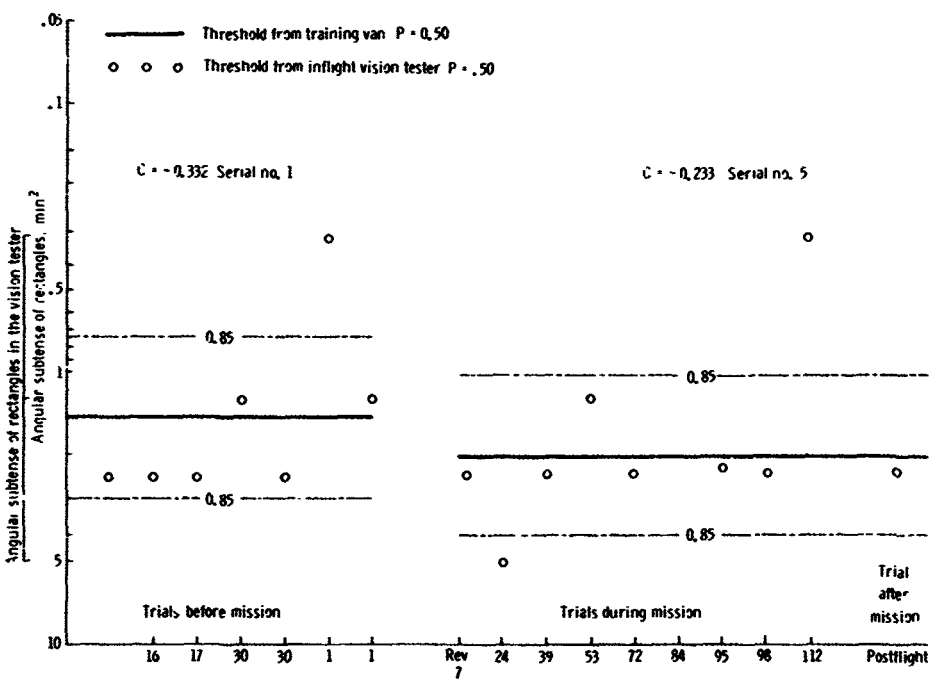

Figure 7. - Rectangle discrimination thresholds for the Gemini V command pilot.

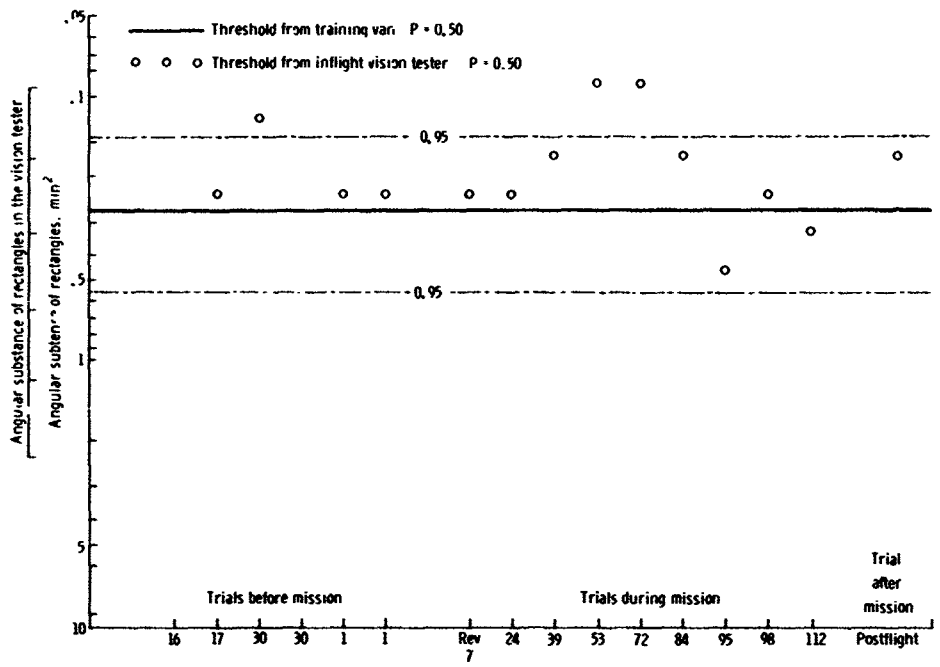

Figure 8. - Rectangle discrimination thresholds (C = -1) for the Gemini V pilot.

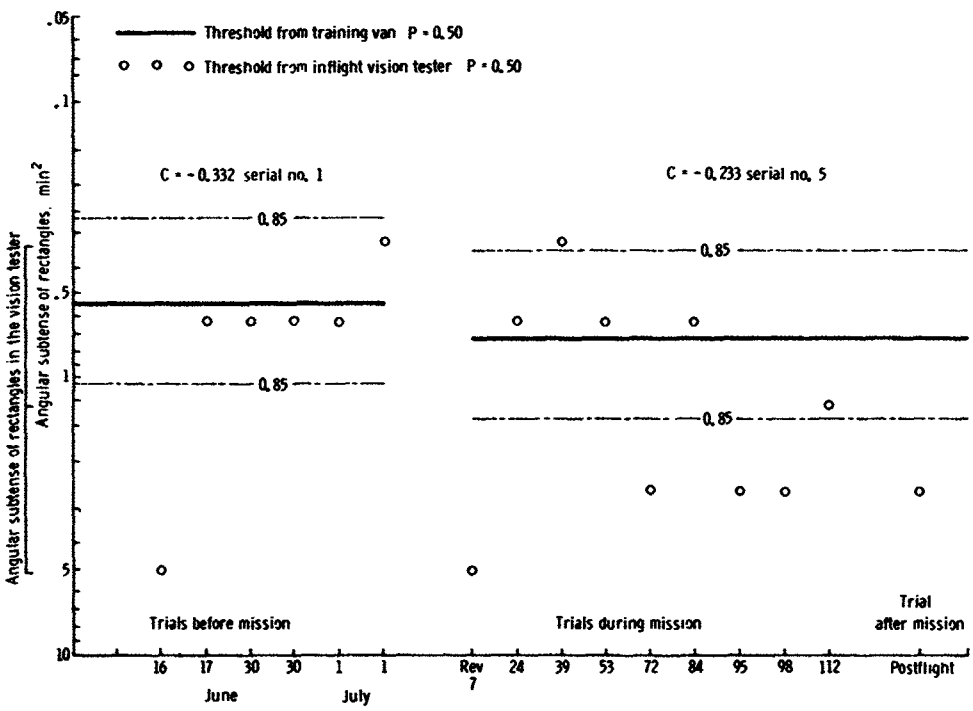

Figure 9. - Rectangle discrimination thresholds for the Gemini V pilot.

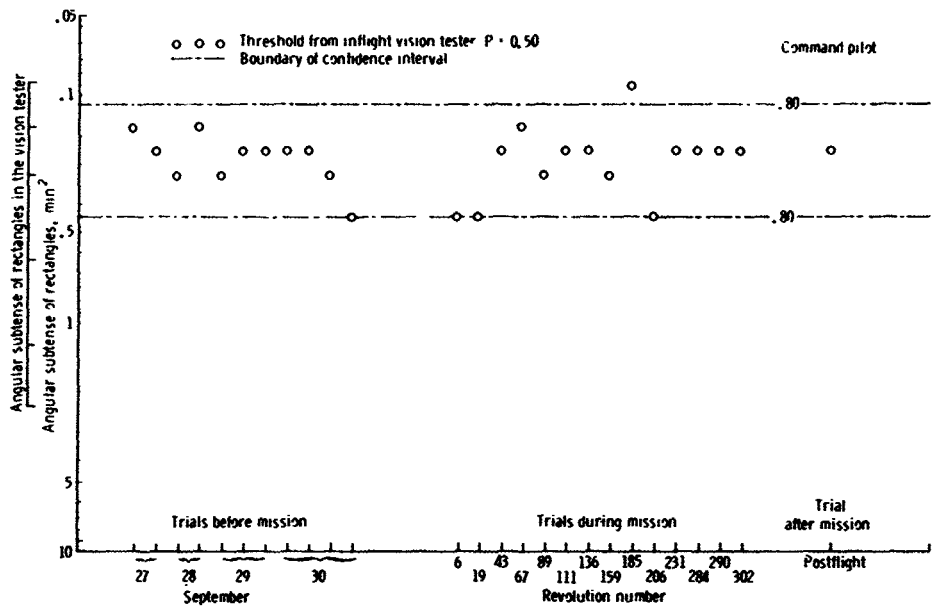

Figure 10. - Rectangle discrimination thresholds (C = -1) for the Gemini V pilot.

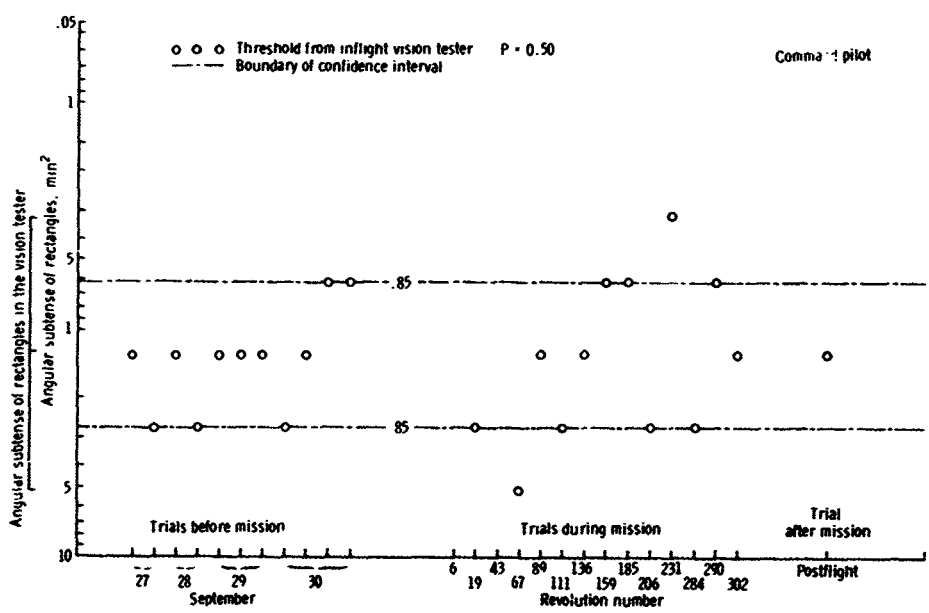

Figure 11. - Rectangle discrimination thresholds (C = -0.233) for the Gemini VII command pilot.

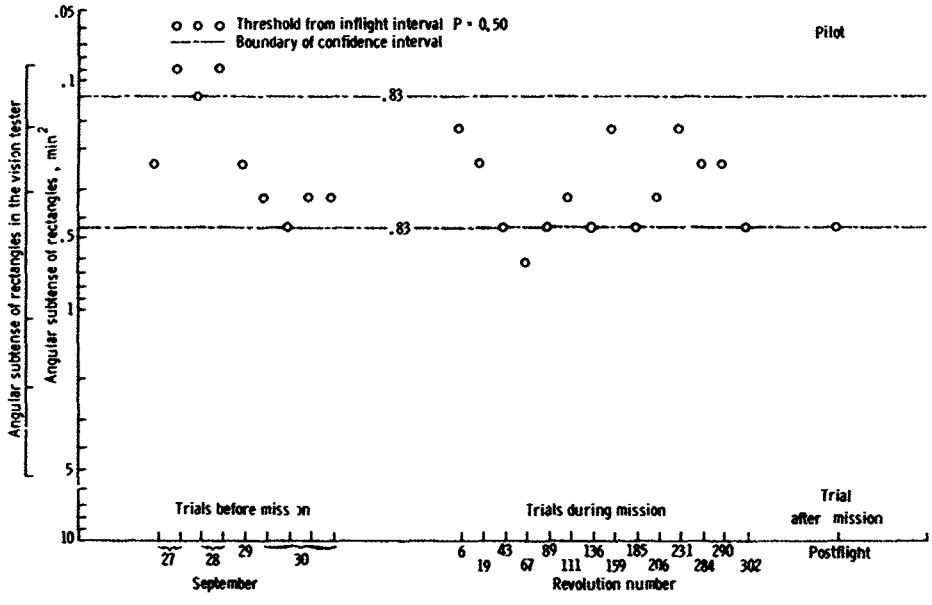

Figure 12. - Rectangle discrimination thresholds (C = -1) for the Gemini VII pilot.

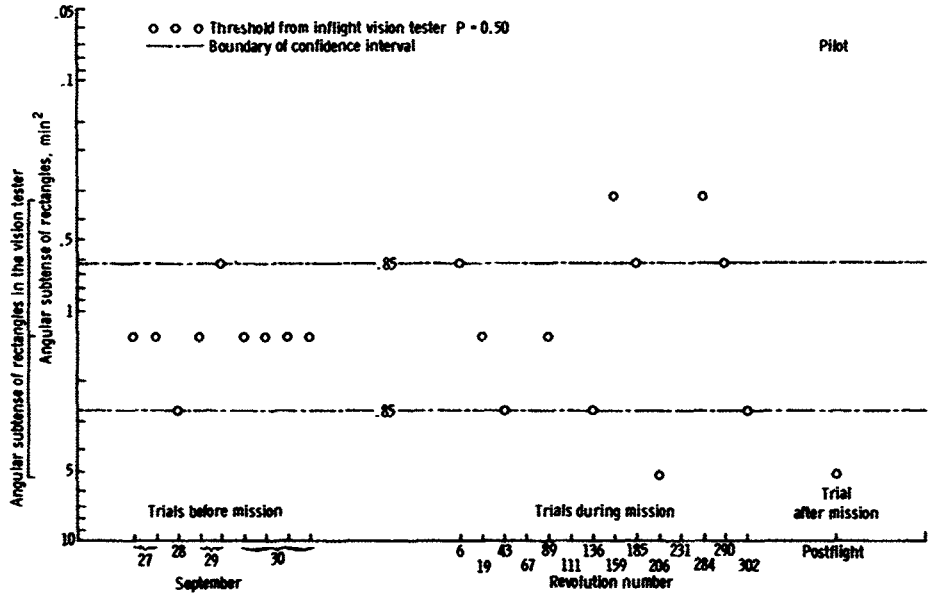

Figure 13. - Rectangle discrimination thresholds (C = -0.233) for the Gemini VII pilot.

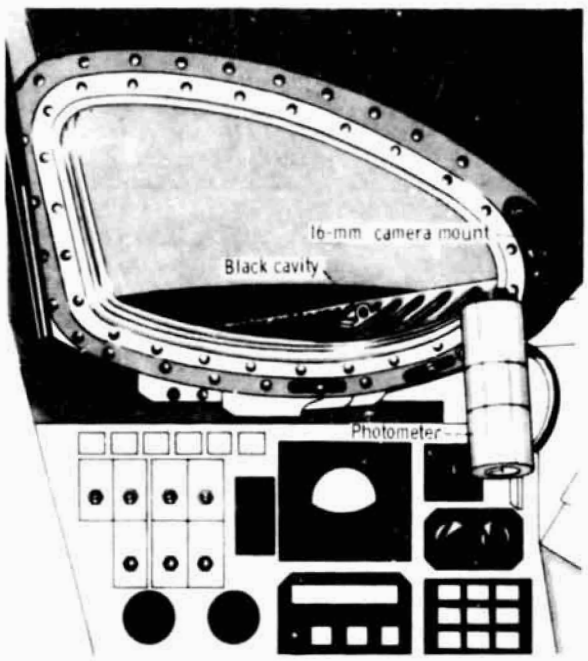

Figure 14. - Location of inflight photometer.

Figure 15. - Components of inflight photometer.

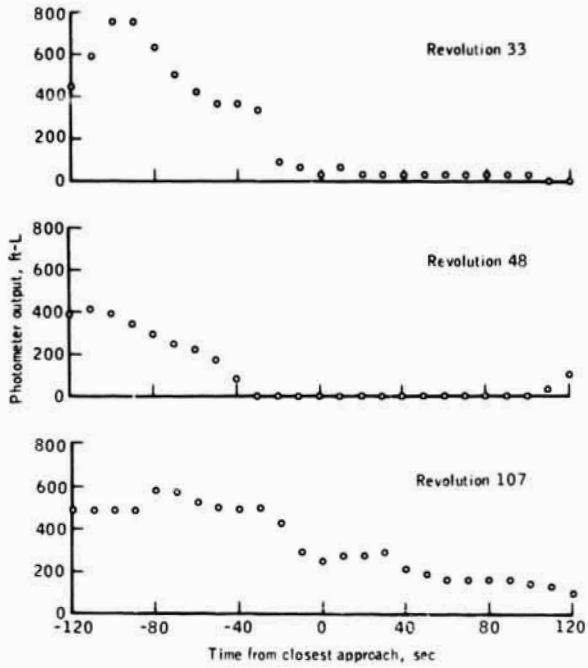

Figure 16. - Photometer data for Laredo, Texas, ground observation site.

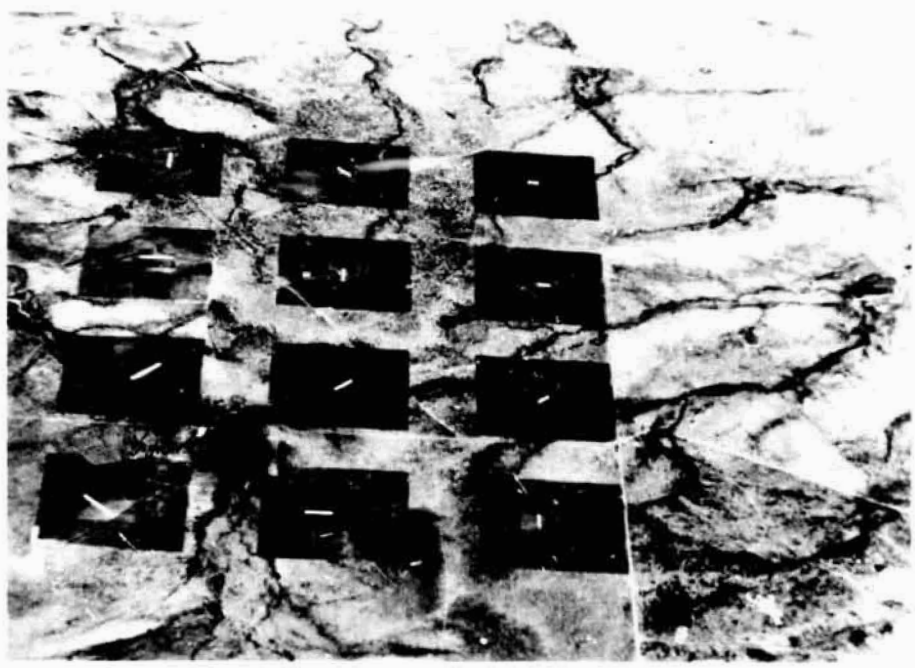

Figure 17. - Aerial photograph of Gemini V visual-acuity experiment ground pattern at Laredo, Texas.

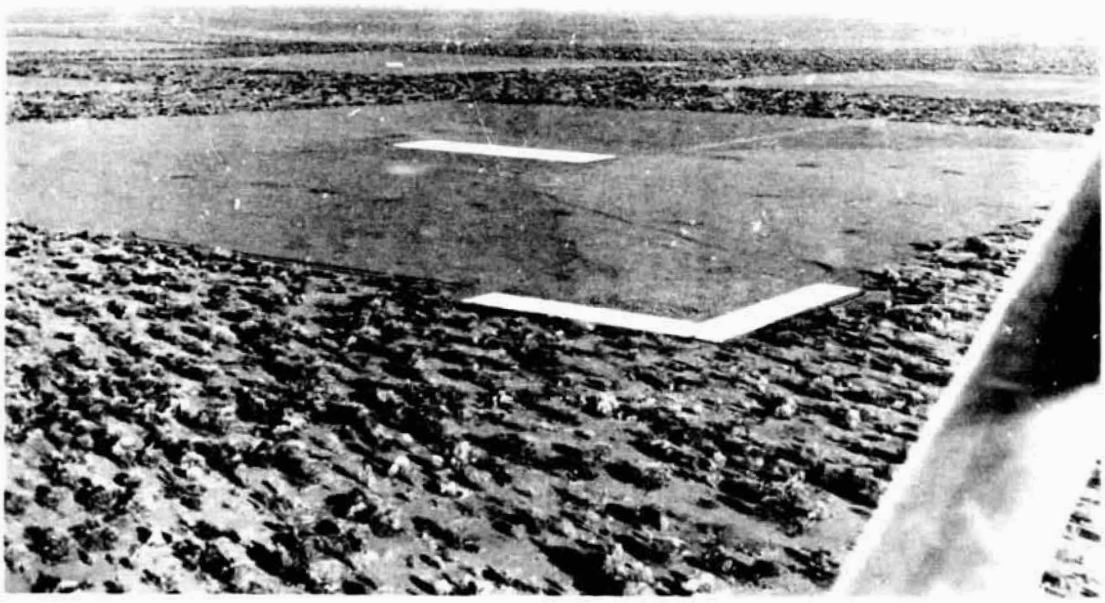

Figure 18. - Aerial photograph of the Gemini V visual-acuity experiment ground observation pattern at Carnarvon, Australia.

Figure 19. - Aerial photograph of the Gemini V visual-acuity experiment ground pattern at Carnarvon, Australia.

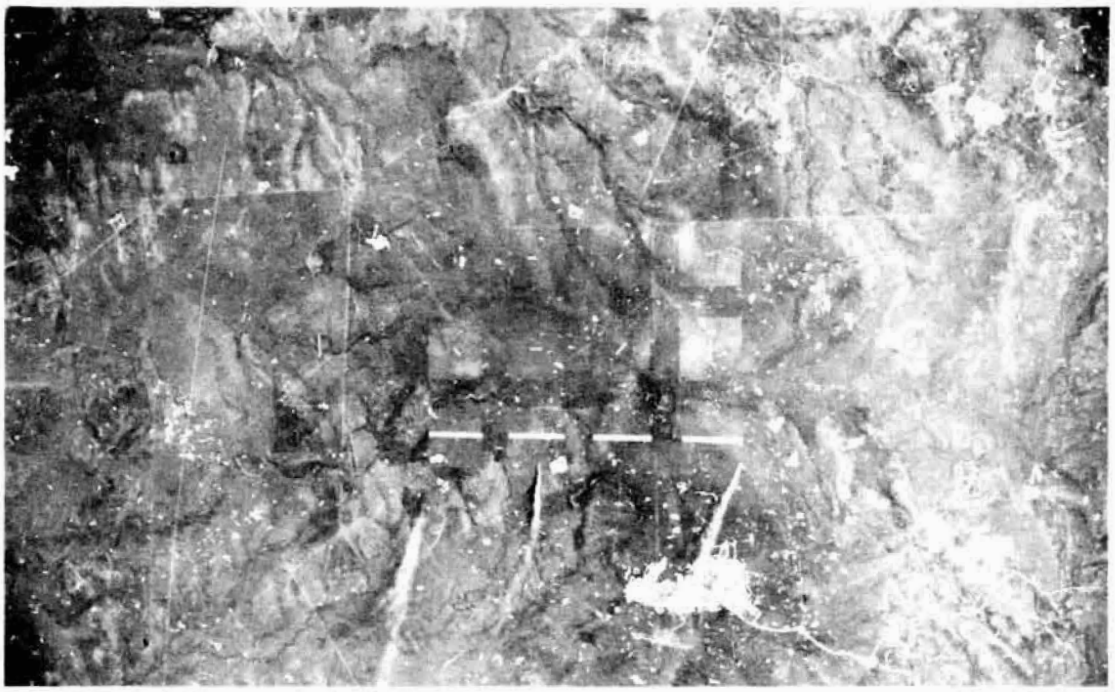

Figure 20. - Aerial photograph of the Gemini VII visual-acuity experiment ground pattern at Laredo, Texas.

Figure 21. - Ground site tripod-mounted photoelectric photometer.

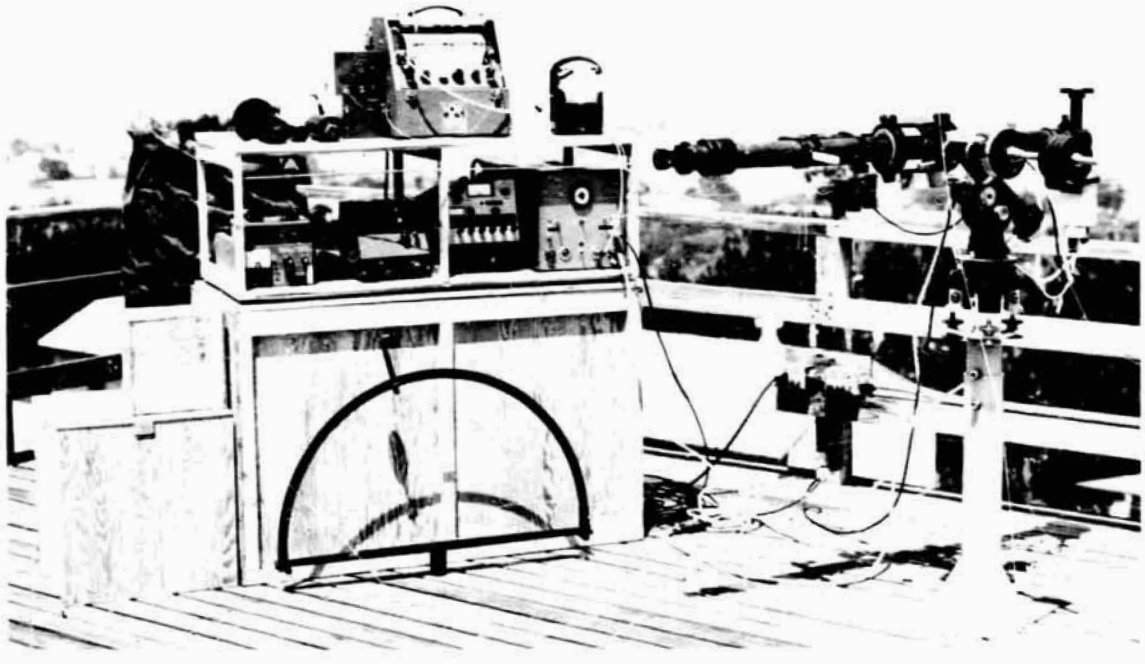

Figure 22. - Ground site photoelectric photometer with recording unit.

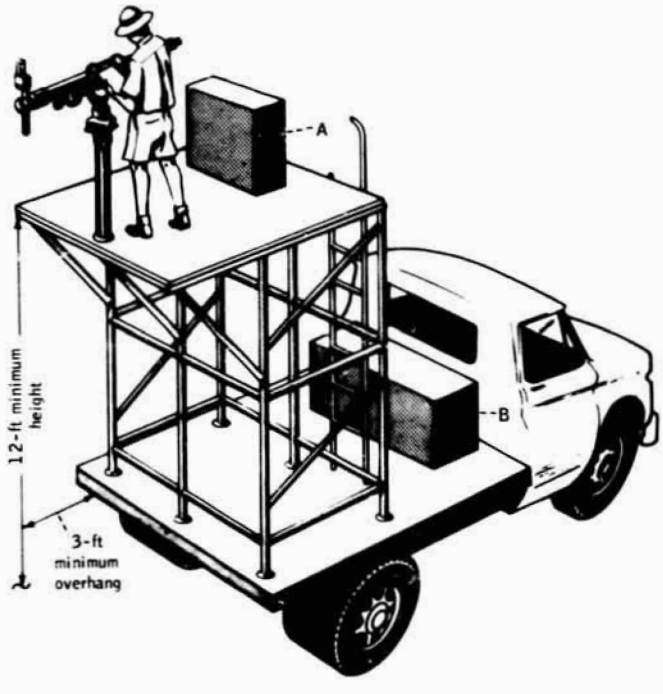

Figure 23. - Drawing of photoelectric photometer mounted on a truck.

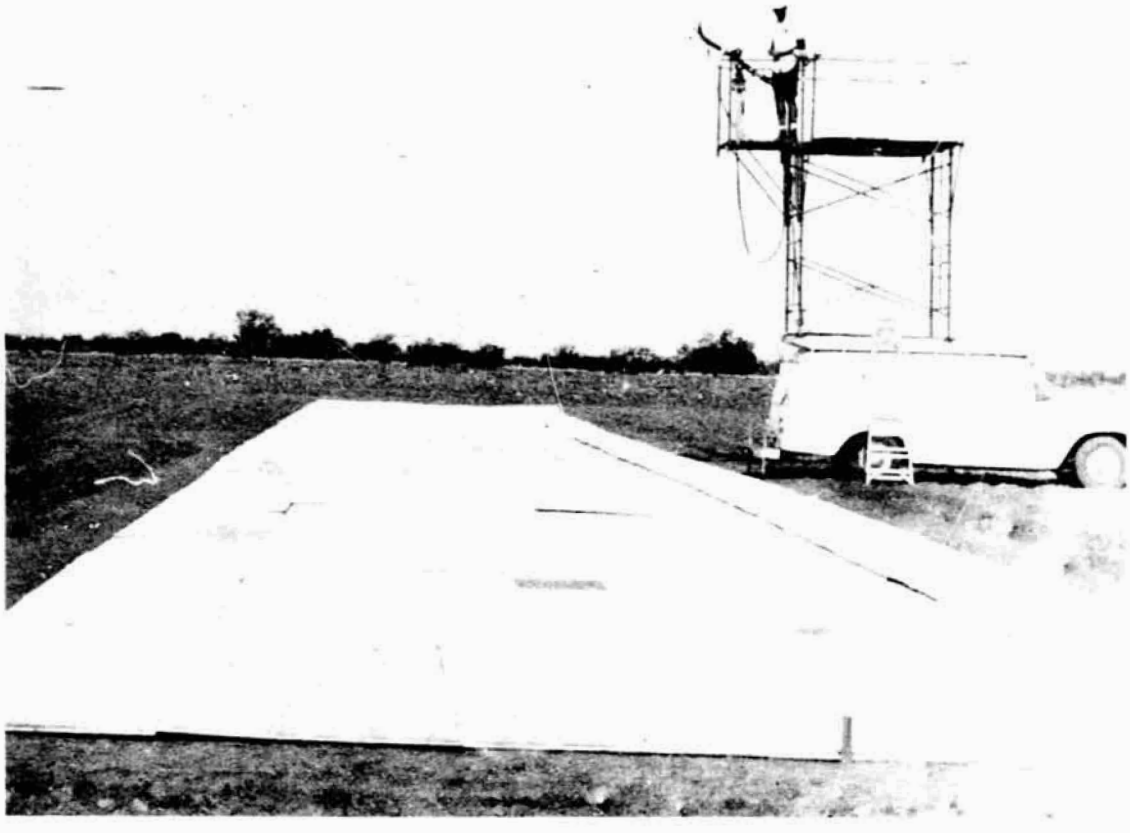

Figure 24. - Photograph of truck-mounted photoelectric photometer.

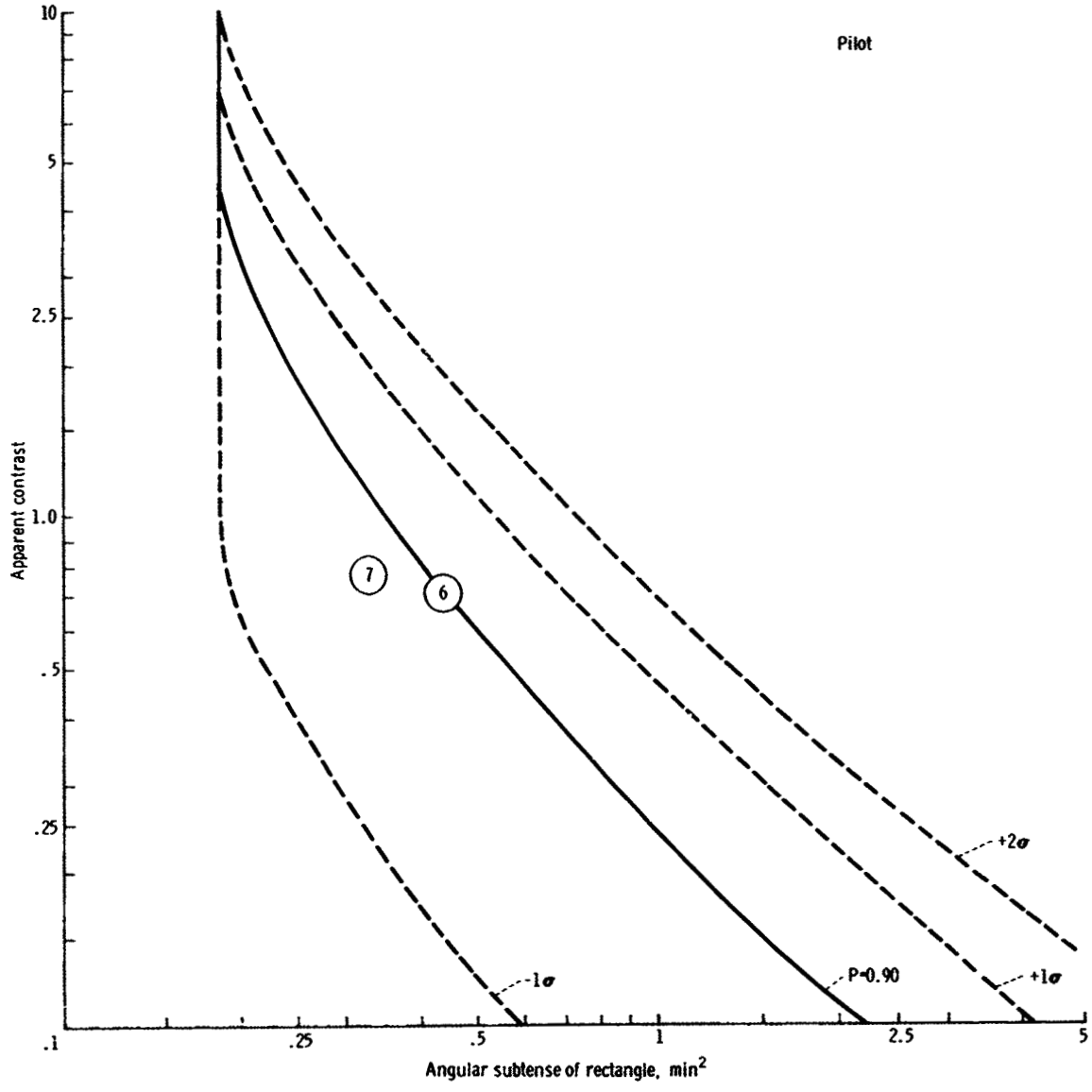

Figure 25. - Apparent contrast compared with angular size of the sixth and seventh rectangles for revolution 48 of the Gemini V mission.

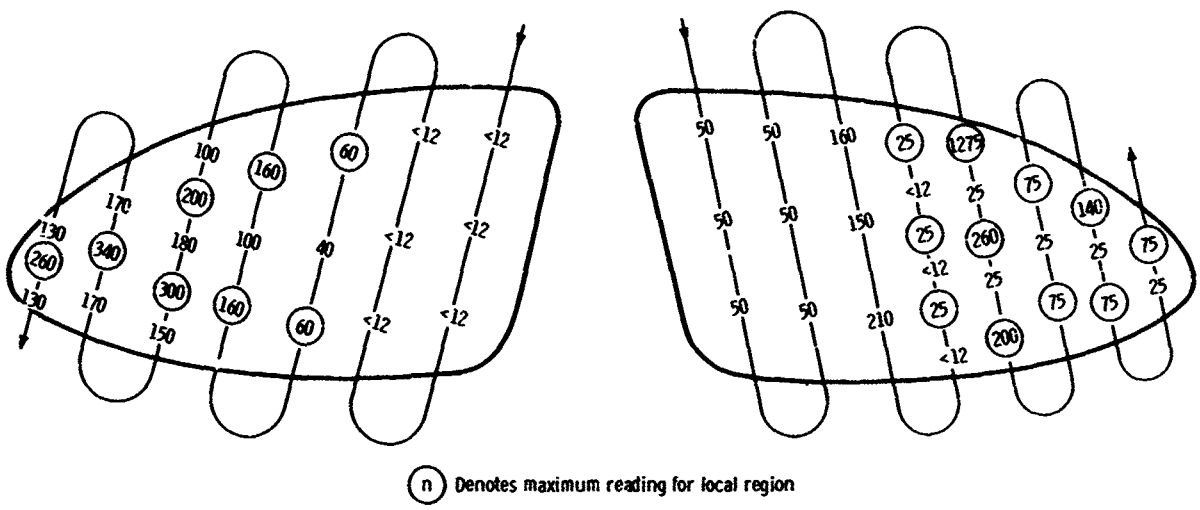

Figure 26. - Numerical results of window scan.

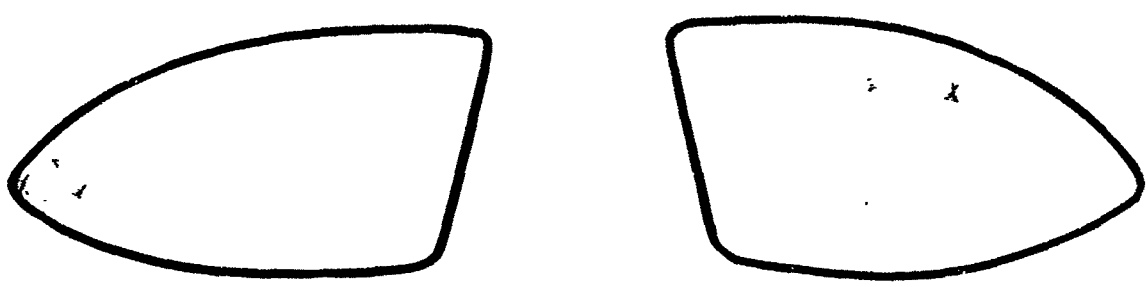

Figure 27. - Shaded pencil sketch of window contamination.

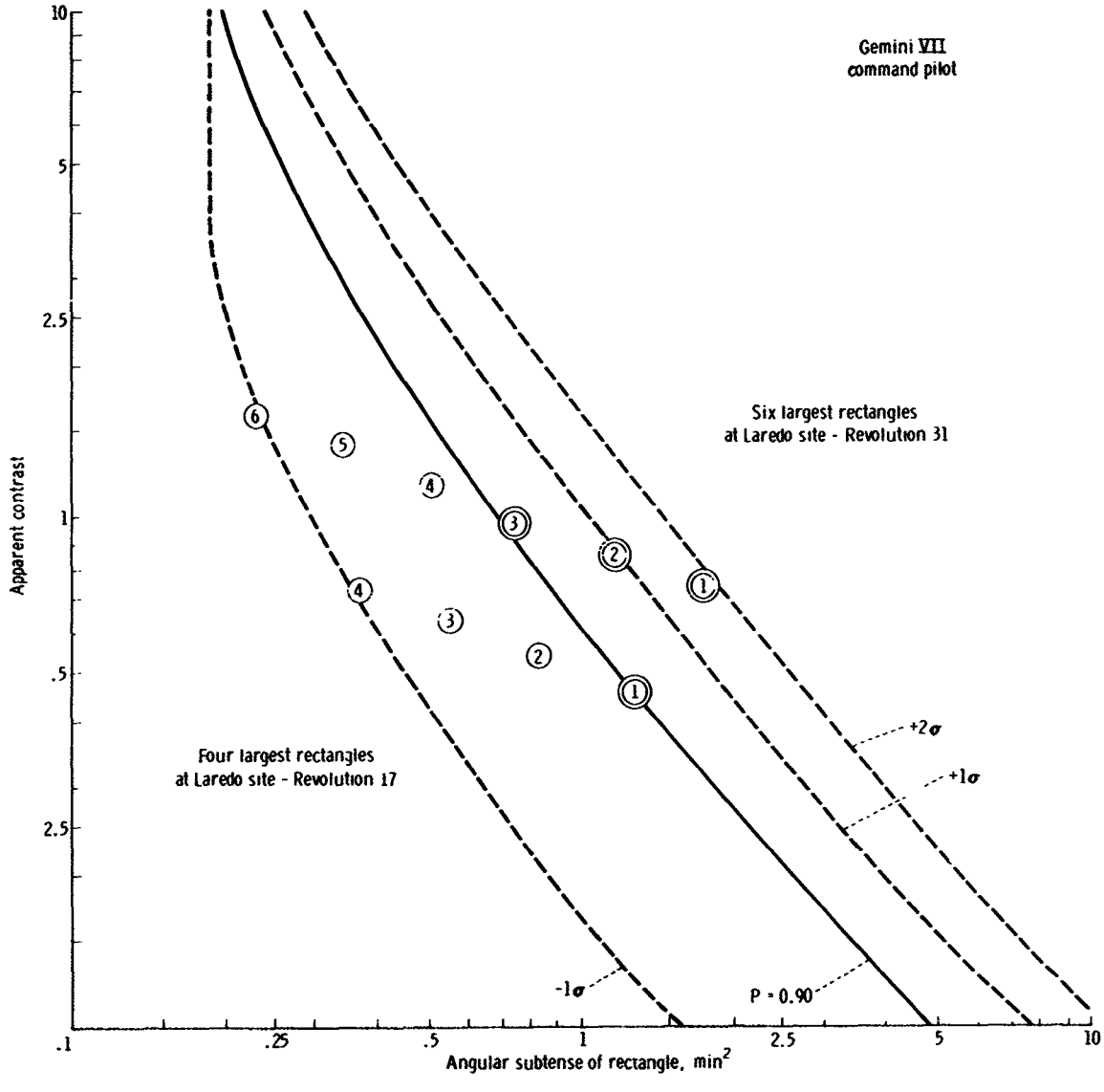

Figure 28. - Apparent contrast compared with angular size of rectangles.

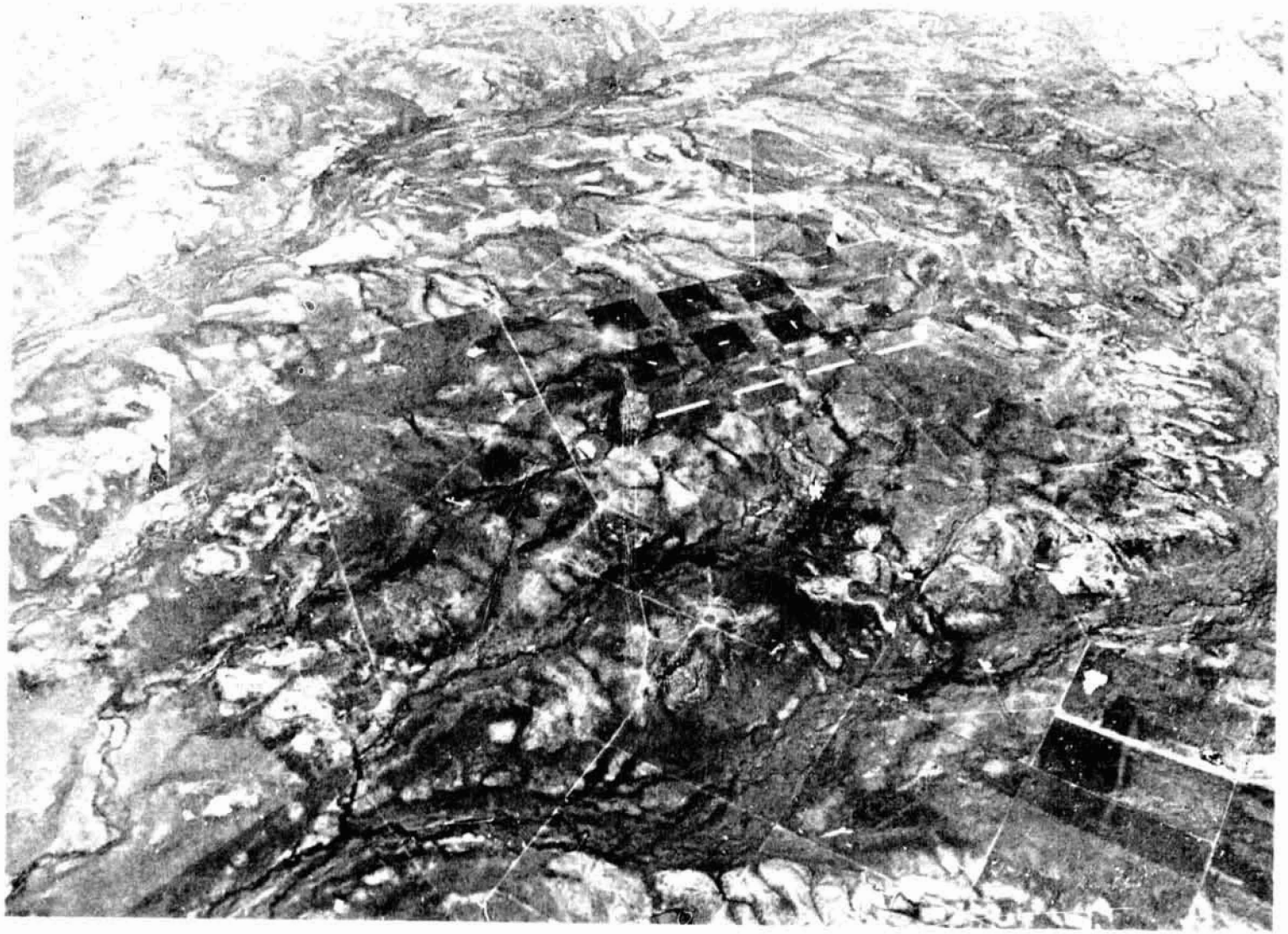

Figure 29. - Visual-acuity experiment ground pattern at Laredo, Texas, photographed by the Gemini VII crewmen during revolution 31.